# THE FUNCTIONS AND ORGANIZATION OF A SOIL MECHANICS SECTION

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Written circa 1945, this paper, written for Budget and Legislature, was instrumental to Bennett's subsequent creation of the "Bureau of Soil Mechanics"

## SYNOPSIS

This paper presents the functions and organization of a soil mechanics section to serve the needs of a highway department or a department of public works. The unit should consist of three groups under the direction of the soils engineer:

1. A soils engineering-administration group
2. An operations group for field work
3. A soil mechanics testing laboratory

The purpose of the unit is to provide soil engineering design and analysis for the various divisions of design, construction and maintenance. The soils engineer should be under the general direction of the chief engineer with authority to serve the divisions and districts of the department.

The personnel of the section should be chosen to provide a balance of training and experience in soil mechanics theory and testing with engineering practice in design and construction in the various fields of civil engineering which the unit must serve.

The continued progress of soil mechanics at the present stage of development depends upon the ability of the soils engineer and his organization to apply the theory and test results of soil mechanics to the practical design and construction of subgrades and foundations.

Soil mechanics deals with the determination of structural properties of soils and the application of these properties through the theory of mechanics to design and construction problems encountered in various fields of civil engineering. A soil mechanics section in a highway or public works department should be established with a broad view point of service to the department in every phase of the adaptation of soil mechanics to the design, construction and maintenance of highways, bridges, buildings, and related structures. Sections for the accomplishment of this engineering service have been established in many of the state highway departments. Some states have performed only random soil surveys and occasional soil mechanics testing by regular highway personnel. Others have organized sections for adequate field investigations and proper use of soil mechanics by personnel with training and experience in both highway engineering and soil mechanics.

It is the purpose of this paper to present the functions and organization of a soil mechanics section for serving a highway department or a public works department. Too often the application of soil mechanics has been considered a laboratory function instead of an engineering function closely allied to the design, construction and maintenance of highways. Soil Mechanics must be an engineering function.

The results of soil investigations should not be reported to designing engineers in terms of soil coefficients only but in soil reports which give definite recommendations on the use of soil mechanics based upon adequate field surveys, soil testing and design analysis.

The application of soil mechanics to problems of civil engineering requires careful study of the design and the relation of soil mechanics to the structural problem. This requirement suggests cooperation between the soils engineer and the designer in arriving at a rational design. The success of soil mechanics in any department depends upon this joint effort.

Practicing engineers, in general, have not had formal instruction in soil mechanics but they have had broad experience in earth work and foundation engineering. It is, therefore, the duty of the soils engineer to study the experiences of the practicing engineers, and make thorough soil mechanics investigations of the conditions in connection with these experiences. The soil conditions surrounding successes and failures can be investigated and the experience evaluated in terms of soil mechanics. By applying the results of these

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past experiences to the design of new highways, the soils engineer can establish the engineering importance of soil mechanics. At the present time, it is important that soil mechanics be presented to engineers through the feasible application of its theories to design and construction problems. The practical solution of problems by the soils engineer will stimulate the use of soil mechanics by engineers and will assist in the establishment and general acceptance of a soil mechanics section.

## ORGANIZATION

The organization of a section to perform soil and foundation engineering on the design, construction and maintenance of highways, bridges, and buildings should be planned to conform to the general organization of the highway department or department of public works. It should function as a service organization to all designing sections of the department and should have the authority and responsibility of applying the principles of soil mechanics to the engineering work of the department. The section may be divided into the following basic groups according to the functions which must be performed:

1. A soils engineering-administration group
2. An operations group for field work
3. A soil mechanics testing laboratory

Figures 1, 2 and 3 have been prepared to show the requirements of organization, functions and personnel for a soil mechanics section, depending upon the extent to which a state desires to establish this service. Figure 1 presents the organization for a state with several highway districts and a large volume of work. Figure 2 gives a minimum organization for the service in a state with a smaller volume of work. Figure 3 shows the minimum professional requirements of education and experience for various grades of soils engineers. These charts may be referred to for the complete picture of organization, functions and personnel discussed in this paper.

The soil engineering-administration group should be organized to supervise and schedule all the work of the section. It should be stationed in the main office of the

department to facilitate consultation with designers and review of plans and specifications. All requests and layouts for soil surveys and foundation investigations should be prepared by this group in cooperation with the designers and transmitted to the field forces. Information should be obtained from the designing engineer on the plans for alignment, grade, wheel load, traffic intensity and type of pavement.

The questions of the designing engineer govern the planning of the soil survey. The geologist and agronomist aid by preparing general geological and soil studies of the areas to be surveyed and give direct assistance to the field forces. Close contact should be maintained with the field forces and frequent conferences held with the designers as progress reports on the survey are available. A study of the soil conditions as they apply to the structure governs the selection of representative samples for testing by the soil mechanics laboratory.

Soil survey and design information should be transmitted to the soil mechanics laboratory with the assignment of the tests. When the soil testing has been completed, the results should be forwarded to the soil engineering group for use in preparation of the final design analysis and soil report containing definite design and construction recommendations.

The operations group for field work should be organized to perform soil surveys, foundation investigations, materials surveys, construction control of compaction and special soil studies of construction problems. District and field laboratories should be attached to this group with equipment for soil classification tests, special sampling tools and equipment for compaction tests. All soil samples obtained in the field surveys must be classified in the district laboratories and representative undisturbed samples forwarded to the main soil mechanics laboratory. The preparation of data on field compaction and control of moisture should be performed by the district laboratories as an aid to the inspection and control of compaction during construction.

The operations group needs to be well equipped with drill outfits and soil survey equipment for both disturbed and undisturbed soil sampling. It is essential that this group have sufficient equipment and men to accomplish the soil survey at the time of the alignment survey so that the results may be used by the designers in the preparation of the original plans. This phase of the work of the soil mechanics section is very important because the testing and design analysis are based upon the proper exploration of soil conditions and representative sampling. Mistakes in the field work cannot be rectified in the laboratory or in the

design analysis. There is no substitute for thorough field investigations.

The soil mechanics section should have a well equipped central laboratory staffed with specialists in soil mechanics testing. The soil mechanics laboratory is a unit of the section under the direction of the soils engineer. This laboratory performs routine soil testing, structural soil testing, and carries on research in soil mechanics and the application of soil mechanics to highway and foundation engineering. It is necessary that the soil mechanics testing in the district and field laboratories be standardized and checked periodically by the central laboratory. The soils engineer in charge of the laboratory should travel to the district laboratories to discuss problems of soil testing and give assistance in establishing uniform procedures.

The soil mechanics section should be responsible to the chief engineer of the department cooperating and giving service to all designing divisions, district offices, maintenance and construction divisions. The section should be in charge of a soils engineer as head, with a competent assistant. It is considered advisable for the head of the section to travel most of the time with the division and district soils engineers, and that the assistant head supervise the office and laboratory. The assistant should coordinate the work of the division soils engineers, the soil mechanics laboratory, and the main office engineering-administration group, as well as conduct the routine administration of the department.

For the purpose of determining policies and procedures and handling soil problems, research and difficulties arising during construction it is advisable to have the head of the section, the assistant head, the division engineers, the office engineer and the laboratory engineer meet at least once a month, and oftener if necessary, to discuss the soil mechanics work throughout the department. Several times a year the district soils engineers should be called into conference to discuss developments in soil mechanics testing, theory and practice.

For a state divided into districts there should be division soils engineers to assist the head of the section in maintaining contact with the soils engineers in the districts. The division soils engineers are responsible to the head of the section and should travel with him on inspections in their divisions. It is recommended that a division soils engineer have not more than three districts under his supervision, so that he can inspect each district at least once a week. The division engineers will bring the problems from the districts to the engineering-administration group in the main office, and transmit information from the main office

back to the districts. They will assist the head of the section in handling construction problems where it is necessary to inspect the site, study the problem, and work out the solution with the district office.

The soils engineers in the districts should be under the direction of the district highway engineer, and the district highway engineer should be responsible for the soil mechanics work so that there will be no interruptions of the line of authority of a district highway engineer. The organization of the soil mechanics section should be planned to establish, as rapidly as possible, the soil mechanics work in the highway districts.

## FUNCTIONS

The main function of a soil mechanics section is to give service to the highway department or department of public works in every phase of the application of soil mechanics to the engineering of the department. The size of the organization and personnel will depend upon the volume of construction carried on by the department. Whether the volume of work is large or small, the functions of a soil mechanics section remain the same. Some of the important problems in which the section can give material assistance in design, construction and maintenance are as follows:

1. Soil surveys for subgrade conditions.

2. Foundation investigations for bridges, buildings, dams and embankments.

3. Materials surveys for borrow, gravel and soil stabilization mixtures.

4. Compaction and moisture control of soils in embankments, subgrades and foundation courses.

5. Selection of excavation material to be used in special embankments and subgrades.

6. Location and design of underdrainage systems.

7. Design of subgrades, including the thickness of subgrade reinforcement for highway pavements under different wheel loads and traffic conditions.

8. Design of soil stabilized base courses, mechanically and with admixtures.

9. Study and prevention of detrimental frost action.

10. Surface sloughing of slopes.

11. Stability of slopes and embankments against circular slides.

12. Construction of embankments through swamps by muck excavation, or by fill settlement methods, using explosives.

13. Settlement and stability analyses of the foundations for high embankments and structures.

14. Loading tests, pile driving tests, and pile loading tests to determine the bearing capacity of soil layers, length of piles, and pile bearing capacity.

15. Permeability and ground water studies for drainage, filtering, seepage, water supply, and disposal.

16. Selection and testing of topsoil.

17. Specifications for earth work.

The work of the soil mechanics section should be done at the same time that the field survey and design of the project is made. It will be necessary in many cases to anticipate the problems and start the drilling operations and soil surveys as soon as the alignment is chosen. The soils engineer can start the soil survey before the final alignment and grade is determined and give material assistance by preliminary borings and thus avoid difficult soil conditions. If difficult soil conditions can not be avoided, the soil mechanics investigations can be started immediately and completed in time to be of value to the design. If necessary the soils engineer can wait until the plan, profiles, and cross sections of a project are completed. This procedure may make the work of the soils engineer easier but requires constant changing of plans which is not desirable.

In the case of bridge and building foundations, the borings should start as soon as the project has been assigned and preliminary information furnished for the layout.. When it is proved that the site is feasible, additional borings may be made to furnish information for the design and construction. It is advantageous for the section to present the soil report at the time of the design. This requires careful scheduling of operations and an adequate organization to perform work. The soil mechanics section should be in constant touch with the work of the department it is serving, and should be notified whenever a project is begun. In this way, the soils engineer has an opportunity to plan his work and produce results in time for the use in design.

It is essential that the results of the soil mechanics investigation be prepared in report form to accompany the plans and specifications when they are forwarded to the final reviewing division. With soil information the reviewing section can pass upon the design, giving due consideration to the conditions surrounding the earth work and foundation. In cases where plans have already been completed for the postwar program, without the benefit of soil investigations, the soil mechanics section should be allowed to review them for problems in the earth work and foundations which would alter the design or materially increase the cost of construction. In these cases, sufficient explorations should be made to check the design and determine the soil conditions for construction, as well as to outline and schedule the use of the soil from the excavation, and the control and inspection of compaction. With the present design requirements of alignment, grade, and site distance, both horizontal and vertical, the occurrence of high embankments and deep excavations is constantly increasing. The alignment requirements necessitate the crossing of many swamps. These should be carefully explored, correct methods of handling determined, depending upon the depth of unsuitable foundation material, the height and width of embankment. With proper information a reasonable and accurate estimate and design can be made for the construction of the project.

Inadequte and incorrect information on soil and foundation conditions is a constant source of claim by the contractor against the state. It is important that sufficient soil and foundation investigations are made and reported in terms that the highway engineer and contractor will understand. It is necessary to review the plans from the standpoint of structural soil mechanics to anticipate and prevent foundation shearing failures, slides and settlements. Increasing intensity of traffic and wheel load requires additional subgrade support and reinforcement as a foundation for the pavement.

Every project must be studied in the field by the soils engineer, as the soil mechanics investigation and the conclusions drawn from it must fit the conditions of construction as they exist at the site. No amount of design or laboratory testing can replace the field inspection in preparing the final soil mechanics report and recommendations for design and construction. It is possible, by this method of approach, for a soils engineer to control the work of his section and keep it within practical limits.

It is necessary for the section to follow through the construction of a project in order to study the difficulties and modify, if necessary, the recommendations of the

soil mechanics section. Condition surveys should be made after construction in cooperation with the maintenance engineers. Soil Mechanics aids in evaluating the performance of a highway as a large portion of the construction and materials consists of earth work. No record of highway performance is complete without a thorough knowledge of the effect of subgrade and underdrainage conditions on the life of the pavement.

## PERSONNEL

The soils engineers should have broad civil engineering experience, as well as training and experience in soil mechanics. If trained soils engineers are not available, the field men should be selected on the basis of their highway experience and their ability to get along with men in the department. They should be willing to study soil mechanics and build up the work of the section in highway districts. The soils engineers in the laboratory and the engineering-administration group must have civil engineering degrees and experience in various branches of civil engineering, as well as formal instruction and advanced degrees in soil mechanics.

The requirements for the various grades of soils engineers should be equal to those of the corresponding grades for civil engineers in the department, with the added requirement of experience and training in soil mechanics. The titles for the grades will vary according to the personnel structure of the department. The head soils engineer should have a rating on an equal basis with the heads of other bureaus and designing divisions.

Figure 3 shows suggested minimum qualifications for soils engineers for various grades. It should be noted that Figures 1, 2, and 3 are suggested with the understanding that they can be applied to the personnel for an organization to carry on the soil mechanics work in keeping with the size and general organization of the department as well as the volume of construction work to be carried on. The functions and organization remain the same and the personnel may be varied to meet the needs of the department.

## CONCLUSIONS

The functions and organization of a soil mechanics section have been presented on a working basis for the establishment of the section and the promotion of its service

throughout a highway or public works department. Soil mechanics should be applied to the design, construction and maintenance of highways, bridges, buildings, and related structures. The functions of the organization include every phase of the use of soil as a construction material or for the foundation and subgrade for highways and structures. The organization must be planned to meet the requirements of the department and in keeping with the volume of construction work to be performed.

The section should be responsible to the chief engineer of the department and under the direction of a soils engineer with authority and responsibility to establish the service and apply soil mechanics to the work of the department. The soils engineer should organize his section with a view to providing soil mechanics theory in a practical manner. Personnel should have experience in highway and general civil engineering, soil mechanics, and foundation engineering to form a well balanced section. The continued progress of soil mechanics at the present stage of development depends upon the ability of the soil mechanics section to apply the theory and test results to the practical design and construction of subgrades and foundations.

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